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MEASURING SLEEP BY WRIST ACTIGRAPH

ANNUAL REPORT

Daniel F. Kripke, John B. Webster,

Daniel J. Mullaney, Sam Messin, and William Mason

APRIL 1980

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Results from the first year of our contract (1978-79) indicated that sleep can be identified from recordings of wrist activity, eliminating the need for costly EEG or unreliable observational sleep recognition procedures.

In the current contract year we have explored alternative activity transducers, transducer placements, and orientations. Results indicate that a crystal transducer is superior to alternative activity transducers, and it responds adequately in any orientation. We have also demonstrated that wrist activity measures are superior to head or ankle measures. (cont. on back)

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20. Abstract, continued.

We have investigated methods of artifact rejection and digital preprocessing in converting analog activity data to a digital activity score. A simple digital filtering technique was effective in cancelling 60 Hz electrical noise, a persistent artifact in our analog data. A method of enhancing as well as compressing activity data by summing changes in activity over a 2-second data epoch yields the best discrimination between sleep and wake.

A computer program to recognize sleep from the digital activity score is being refined. Once an optimal algorithm for retrospective sleep recognition has been derived, its success in prospectively recognizing sleep from wrist activity will be evaluated.

A portable model of a wearable prototype digital actigraphic recorder has also been manufactured.

SUMMARY

We report the second year (ten months) of what is conceived as a three-year effort. Results from the first year of our contract (1978-79) indicated that sleep can be identified from recordings of wrist activity, eliminating the need for costly EEG or unreliable observational sleep recognition procedures. In the next two years, we proposed a technical definition of a miniature digital actigraphic recorder capable of measuring and storing activity information, yet compact enough to be worn on a wrist.

To perfect this system in the current year we have explored alternative activity transducers, transducer placements, and orientations. Results indicate that a crystal transducer is superior to alternative activity transducers, and it responds adequately in any orientation. We have also demonstrated that wrist activity measures are superior to head or ankle measures.

We have investigated methods of artifact rejection and digital preprocessing in converting analog activity data to a digital activity score. A simple digital filtering technique was effective in cancelling 60 Hz electrical noise, a persistent artifact in our analog data. A method of enhancing as well as compressing activity data by summing <u>changes</u> in activity over a 2-second data epoch yields the best discrimination between sleep and wake.

A computer program to recognize sleep from the digital activity score is being refined. Our current efforts utilize the computer to evaluate the contribution of a number of potential discriminators between sleep and wake. Given knowledge of actual sleep/wake status of an activity record, the weighting of each discriminator is adjusted until a maximum percent agreement is reached. Once an optimal algorithm for retrospective sleep recognition has been derived, its success in prospectively recognizing sleep from wrist activity will be evaluated.

A portable model of a wearable prototype digital actigraphic recorder has also been manufactured.

FORWORD

For the protection of human subjects the investigator has adhered to policies of applicable Federal Law 45CFR46.

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INTRODUCTION

Sleep loss and combat fatigue are increasing concerns for the modern army. A future war is likely to be extremely brief and intense, with victory and defeat determined in a few days or weeks. Soldiers using technically sophisticated modern weaponry will have little time for sleep, and plans must be made to enable personnel to perform effectively throughout the duration of a combat of unprecedented intensity. American troops may have to enter combat immediately after airlift to remote parts of the world, and plans must be developed to minimize the effects of jet lag on personnel performance.

Military medicine therefore needs a practical method of quantifying sleep both to design personnel strategies and for potential monitoring of troops in actual field deployments.

Traditional physiologic methods for monitoring sleep through EEG-EOG-EMG recordings are completely impractical in actual or simulated combat settings, and subjective monitoring has been shown to be unreliable (1). In addition, both physiologic measures and observational methods for measuring sleep are costly, and considerable time is necessary to quantify sleep by scoring polygraph records.

We are developing a wrist activity monitoring technique as a solution to these problems.

Employing Delgado's (2) telemetric activity recording device, Kupfer et al (3) and Foster et al (4, 5) described the use of activity data for quantifying sleep and assessing sleep quality in humans. Encouraged by the high correlations between EEG and actigraphic estimates of sleep -- 0.84 and 0.88 in two separate studies (6, 7) -- Kripke et al (8) developed a system in which a piezoelectric crystal worn on a watchband recorded wrist activity onto a Medilog cassette tape recorder worn on a belt (Figure 1). With this crystal actigraph, Kripke et al (8) obtained a correlation of 0.98 between sleep duration determined from wrist activity and the EEG in five subjects.

A more exhaustive study of 63 normal subjects and 39 hospital patients with various sleep disorders was conducted under the first year of our contract (DAMD-17-78-C-8040, 1978-79). All-night recordings of wrist activity, EEG, EMG and EOG were collected simultaneously on a 4-channel cassette. Each minute was scored as either sleep or wake by one rater using only activity data, and a second rater using only EEG-EOG-EMG data. The raters agreed on 94.5% of the minutes (96.3% for non-patients). Estimates of each subject's total sleep time with the two methods were correlated 0.89 (0.95 for non-patients). These results indicate that the wrist actigraphic analog recording contains sufficient information to produce a highly reliable scoring of sleep.

On a cost-benefits basis, the wrist activity method was shown to supply greater precision than EEG for equal expense (because more subjects could be studied) and better applicability to non-laboratory settings. Nevertheless, further development is needed to perfect a device which adequately estimates sleep and is small enough to be worn in combat.

To meet this need, in 1979 we proposed a two-year contract to perform technical design definition of a digital wrist activity recorder which would be suitable for combat use. Our basic concept envisions a two-part system. The first part, to be worn entirely on the wrist, would consist of an activity transducer, microprocessor-based signal preprocessor, and read/write digital memory. The second part, to be field-deployable but not wearable (perhaps the size of a suitcase), would consist of a microprocessor-based readout device which would perform sleep-wake recognition, statistical summarization, and print out a summary report.

In the 1979-1980 year, we planned to define the optimal transducer design, the optimal transducer placement, and the hardware-software requirements of such a device, at the same time developing a breadboard design of a testable portable digital activity monitoring device. In the 1980-1981 year, we plan to program and test a prototype portable device and verify its performance, concluding with definition of technical requirements of a microminiaturized device which would be field-deployable. In 1981, we could then propose actual construction and deployment of combat-applicable sleep monitoring devices.

Here we summarize ten months of the 1979-1980 work.

GOALS OF THIS YEAR'S WORK

1. Determine the optimal activity transducer design.

2. Determine the requirements for omnidirectionality.

3. Determine optimal transducer placement on the body.

4. Develop a digital activity preprocessing algorithm for use in the wearable device.

5. Develop a sleep/wake recognition program.

6. Develop in breadboard form a wearable prototype digital activity monitor to verify design principles before microminiaturization.

TRANSDUCER OPTIMIZATION

Since conversion of mechanical motion to an electrical signal is the basis of actigraphic recording, we believe that optimization of the recording transducer is extremely important to the final goal. Although our current piezoelectric transducer has performed admirably, we wished to test other forms of accelerometers and motion detectors before settling on any transducer design. In general, since we found most of our failures to discriminate sleep and wake were due to failures to detect motion during wake, maximal sensitivity to motion is the major design criterion. Several prototypes of our own design including water- or mercury-filled spheres were rejected because they failed to respond reliably. A number of commercially available transducers were considered, and two were selected for comparison. A single-plane accelerometer ordered from Grass Instruments was delivered in late April, 1980, so testing of this device is still being completed. Testing of an activity transducer consisting of six mercury tilt switches (Vitalog Corp.) is described here.

Method

The Vitalog transducer was mounted in a small box (3.7 x 3.5 x 5.6 mm) along with a crystal actigraph. A 1.35 V battery and resistive voltage divider was placed in series with the Vitalog device so that the voltage switched by the tilt switches matched the input requirements of the Medilog cassette recorder. The two devices were connected to two channels of the Medilog and four subjects wore the box on their wrists for a total of six nights. The two channels were played back simultaneously on a polygraph at an effective rate of 32 mm/minute , relative to real time.

Results

In general, the crystal actigraph measured activity at many times when the Vitalog did not. Figure 2 shows a representative example of the polygraph writeout of the simultaneous Vitalog and actigraph signals. In our entire sample, there were no examples where the Vitalog transducer detected activity not recorded by the crystal. In summary, the tilt switch array missed much of the activity which was detected by the crystal transducer, and it would often have made recognition of wakefulness impossible.

Discussion

The crystal actigraph is clearly more sensitive to wrist activity than the tilt switch activity transducer. One reason for this difference may be fundamental to the design of the two devices. The Vitalog transducer features an array of six mercury tilt switches distributed around the major axes, and consequently measures changes in attitude, or rotation. It is possible to move the transducer without rotating it around any axis,

and without closing any of the switches. The frequency of the signal is a function of the number of axes rotated through and the magnitude of rotation in each axis. The crystal actigraph, on the other hand, is sensitive to any acceleration. The results of this study indicate that wrist activity is better described by acceleration than by rotation. We expect to compare the crystal actigraph and accelerometer in a similar design. It is unlikely that the accelerometer will prove advantageous, however, for it is not omnidirectional.

TRANSDUCER OMNIDIRECTIONALITY

The axial design of the crystal actigraph can be expected to make it most sensitive to one axis of acceleration and one axis of rotation. The eccentrically spring-mounted weight which excites our piezoelectric crystal allows the transducer to respond to accelerations or rotations in any axis, but its directional sensitivity is not equal in every axis. It was therefore important to determine the directional sensitivity of the actigraph, and if significant directionality was found, to specify the orientation which best detected activity.

Methods

Three crystal actigraphs were mounted in each major axis within a single small box (3.7 x 3.5 x 5.6 mm) and connected to three channels of a Medilog recorder. Six subjects wore this 3-axis actigraph on a wrist for a total of ten nights. The three channels were replayed simultaneously onto the polygraph at an effective rate of 32 mm/minute.

Results

An example of the 3-axis actigraph recording is presented in Figure 3. This example is representative of the entire sample, and reveals that although the recorded activity signal was frequently somewhat larger in one axis than another, there were virtually no instances in which activity detected in one axis was not registered by all three transducers. No orientation seemed superior.

Discussion

Although of axial design, the crystal actigraph shows adequate omnidirectionality. The orientation of the actigraph on the wrist does not seem critical.

TRANSDUCER PLACEMENT

Although we have typically mounted actigraphs on the non-dominant wrist, this decision was based on Kupfer's procedure and lacked experimental validation. To determine which placement would register the most activity, and therefore be most likely to discriminate sleep and wake, we surveyed several possible placements. We chose the head rather than any placement on the body trunk because we reasoned the trunk could not be displaced without moving the head, while the reverse was not true. We had also observed respiratory artifacts when the wrist was near the abdomen or ribs, and we wished to minimize these. We also explored the other limbs.

Methods

Four crystal actigraphs were mounted in separate boxes (3.5 x 4.4 x 1.7 mm) and connected to the four channels of a Medilog recorder. Nine subjects completed 22 recordings with the actigraphs worn simultaneously on each wrist, the forehead and the right or left ankle. The assignment of actigraphs to locations was counterbalanced to control for variation in the sensitivity of individual crystals. The four channels were replayed simultaneously to four channels of the polygraph at an effective rate of 32 mm/minute.

Results

Figure 4 shows a typical 4-channel activity record. In order to evaluate the measure of activity from each site in the entire sample, a rater ranked the four channels for the amount of activity measured, without knowledge of which location corresponded to which channel. Results of this ranking are presented in Table 1. Of the 19 records judged adequate for scoring, a wrist was judged best in 18 cases. Furthermore, the best ranking was equally distributed between left and right wrists (all subjects were right-handed).

Discussion

This study showed that wrist placement often detects activity that head or ankle placement fails to detect. The reverse was rarely true, although a few instances were observed in some of the subjects. Other recordings of tibialis EMG in sleep disorders patients have taught us that ankle motion during sleep is common among some subjects, providing a further reason to prefer the wrist. It was also found that there is little difference between wrists. Either wrist may be chosen at the preference of the subject.

DIGITAL PREPROCESSING

In our laboratory, analog activity records are scored by replaying the cassette tape at approximately twice the recording speed to a polygraph, then visually scoring the polygraph record. The procedure is therefore time-consuming (about one-half of the actual time of the sleep recording for the writeout alone) and requires sophisticated apparatus and a trained scorer. The Medilog recorders themselves, while suitable for ambulatory subjects, are too delicate and bulky for field use or actual combat deployment. Our current method also records data with a resolution on the order of 8 bits and a bandwidth of approximately 0.1-100 Hz, that is, approximately 70,000,000 bits of information in a 24-hour recording. It is obvious that to realize a practical digital activity storage device, some form of data compression must be utilized.

Data compression should also incorporate a measure of artifact rejection, for our current actigraphic analog recordings are sometimes contaminated by low-voltage 60 Hz electrical noise, by other kinds of electronic artifact, or by the small movements which occur when the wrist is placed on the chest and is displaced by respiration. The digital actigraphs currently employed at Walter Reed and NIMH are sensitive to vehicular vibrations. While a human judge may recognize this activity as artifact, a computer would not unless specifically programmed to recognize and ignore such activity patterns.

To find an optimal data compression approach, we played back a series of activity records into the A/D converter of our HP 2100 computer system. Ten data compression algorithms combining filtering, summing, squaring, differencing and threshold detection were utilized, and the effectiveness of these algorithms in discriminating sleep and wake (as scored by hand analysis of actigraph) and rejecting 60 Hz noise was compared.

Methods

Figure 5 illustrates the procedure in block diagram form. Activity recordings on Medilog tape were played back at 60 times recording speed to a Sangamo instrumentation recorder running at 30 ips. The Sangamo tape was then rewound and played back at 15/16 ips. The resulting actigraph signal was therefore 60x(15/16)/30, or 1.875 times actual recording speed. This analog signal was written out on one channel of the polygraph running at 60 mm/minute, for an effective rate of 32 mm/minute relative to real time. At the same time, the analog signal was fed to the analog-to-digital converter (A/D) operating at an actual rate of 450 Hz, or an effective rate of 450/1.875 or 240 Hz relative to real time. The digital output of the A/D converter was then processed by the computer (details will follow) and the output stored on disc. The computer also generated a time code representing one minute of real time which was written on the polygraph record to allow the disc and polygraph records to be compared.

The program for processing and storing digital activity scores explored ten digital preprocessing algorithms and tested a simple digital filtering technique for rejecting 60 Hz electrical interference. A listing of the program is included in Appendix 1. The first stage of the program is the digital filter. The conversion rate of 240 Hz (real time) is exactly four times the frequency of 60 Hz electrical noise (which might come from an electric blanket or clock near the bed during sleep). Since this 60 Hz signal alternates between positive and negative, four (or any even integer) regular samples of voltage per cycle will sum to zero. Thus if every four conversions are summed, 60 Hz interference will cancel. Evidence will be presented indicating the effectiveness of this simple filtering technique. A 120 Hz artifact would also be cancelled and 50 Hz artifact and most high frequencies would be at least partially attenuated.

In addition to the simple sum of every four conversions ($\overset{4}{\Sigma}y$) the sum of every four squared conversions ($\overset{4}{\Sigma}y^2$) was also calculated and 120 of each of the two sums ($\overset{4}{\Sigma}y$ and $\overset{4}{\Sigma}y^2$) were accumulated for each two-second data epoch. A total of ten transformations of $\overset{4}{\Sigma}y$ and $\overset{4}{\Sigma}y^2$ were calculated and stored on disc for each two-second epoch. The ten transformations were: 1) The simple sum of the simple sums $\overset{120}{\Sigma}(\overset{4}{\Sigma}y)$, 2) The simple sum of the squared sums $\overset{120}{\Sigma}(\overset{4}{\Sigma}y^2)$, 3) The sum of the simple sums squared $\overset{120}{\Sigma}(\overset{4}{\Sigma}y)^2$, 4) The sum of the squared sums squared $\overset{120}{\Sigma}(\overset{4}{\Sigma}y^2)^2$. The next four transofmrations summed a "difference score" on the same four quantities. This difference score is ten times the value of a given item minus the value of the preceding and following five items: $\overset{120}{\Sigma}f(x_i)$, where

$$f(x_i) = 10 * x_i - (x_{i-5} + x_{i-4} + x_{i-3} + x_{i-2} + x_{i-1} +$$
$$x_{i+1} + x_{i+2} + x_{i+3} + x_{i+4} + x_{i+5}).$$

Transformations 5 through 8 replace x in the above expression with 5) $\overset{4}{\Sigma}y$, 6) $\overset{4}{\Sigma}y^2$, 7) $(\overset{4}{\Sigma}y)^2$, 8) $(\overset{4}{\Sigma}y^2)^2$. Finally, transformation 9 counts the number of $\overset{4}{\Sigma}y$'s per epoch exceeding 90% of the maximum $\overset{4}{\Sigma}y$, and transformation 10 counts the number of $\overset{4}{\Sigma}y^2$'s exceeding 90% of the maximum $\overset{4}{\Sigma}y^2$. The most significant 16 bits of each transformation were then stored on disc for each 2-second epoch.

Seven all-night wrist activity records were digitized according to the procedure described above. Portions of the digitized records were displayed visually on our plotter to examine the behavior of the 10 transformations during different forms of activity. (One such plot is presented in Figure 6 along with the polygraph record of the same five-minute interval.) A more rigorous analysis of the adequacy of each transformation was obtained by first visually scoring each of the seven polygraph activity records for sleep/wake and merging the sleep/wake score to the digitized data. A separate analysis program was then written (Appendix 2) to recognize sleep from the digitized activity data and determine the maximum percent agreement between the computed and known sleep/wake status. It

should be pointed out that this sleep recognition program is not the ultimate sleep recognition program currently under development but a simpler procedure which decides that a minute is "wake" if the activity score in x of the 30 epochs exceeded a threshold of y. The x, y parameter space was then searched and the maximum percent agreement determined for each record and each transformation. This result served to compare the discriminating power of the ten preprocessing algorithms. The thresholds producing the best agreement were calculated individually for each record and therefore differed from record to record. In practice, a transformation would have to discriminate sleep from wake using the same threshold for all records. The procedure was thus repeated except that the maximum percent agreement was calculated using the single best threshold for all records taken together.

Results

Figure 6 shows the plotter display and polygraph writeout of a five-minute portion of a record contaminated with 60 Hz noise from an electric blanket. The ten horizontal traces on the plot represent the ten digital transformations of the analog activity displayed on the polygraph. The vertical lines on the plot separate minutes, which are also marked and labelled with a binary code on the polygraph paper. Of particular interest in this figure is the contrast between traces 1, 3, 5 and 7 and traces 2, 4, 6, 8, 9 and 10 during periods of electric blanket noise. Since even-numbered transformations square voltage prior to summation, all values are positive and cancellation of 60 Hz noise cannot occur. Transformations 1, 3, 5 and 7 do not square voltage prior to summation and cancellation of noise can and does occur. The absence of noise in these latter traces indicates the effectiveness of the simple digital filtering technique.

The potential of each of the ten methods of digital preprocessing was evaluated by calculating the maximum percent agreement between known sleep/wake status and sleep/wake status computed using each of the ten transformations. Table 2 summarizes the maximum percent agreement when the optimal threshold was found for each record individually. Table 3 presents the rank order of maximum percent agreement for each record. Despite some variability, the indication from these data is that transformations 5 and 6 were superior to the others. Maximum percent agreement using the single best threshold for all records is presented in Table 4, and rankings are presented in Table 5. (Transformations 1, 2 and 10 were not tested since they were judged inadequate after the first procedure.) Transformation 5 emerged as the best overall. Although this was a retrospective procedure not strictly comparable to prospective scoring, it was encouraging that the median percent agreement obtained for the best algorithm was 0.91.

Discussion

Since the volume of data generated by frequent A/D conversions of analog activity records could not possibly be stored or managed in its entirety, strategies for data compression were evaluated. In order to preserve some resolution, the basic data epoch was set at two seconds. To utilize the simple 60 Hz noise filter resulting from summation in even integer multiples of 60 Hz, an A/D conversion rate of 240 Hz was selected. Within these constraints, ten algorithms for preprocessing the analog voltage reading were evaluated and it was concluded that a measure of voltage change was preferable to simple or squared summation, or threshold detections. The 60 Hz noise rejection filter was also effective and is an important feature of the transformation finally selected.

SLEEP RECOGNITION

Our experience with scoring activity records suggests that a judgement whether the subject is asleep or awake can be based on reasonably simple and definable criteria with reasonable reliability. If there is no movement at all for several minutes, the subject is judged asleep. The exact number of minutes quiescent required for scoring sleep depends on the previous and subsequent evidence of wakefulness, and it is here that some complex judgements are required. Periods when only occasional brief movements are detected in the record are also difficult to score. Nevertheless, we feel scoring criteria can be reduced to a logical decision system and implemented in a field-transportable computerized readout device.

We have decided to attack the problem of discerning the optimal rules for sleep recognition by constructing an expression with a number of potential discriminators, then allowing the computer to vary the weighting of each factor in an adaptive search procedure. The expression presently being tested is:

$$D = s * (c_1T_1 + c_2T_2 + c_3T_3 + c_4T_4 + c_5T_5 + c_6T_6)$$

where s is a scale factor, c_1 to c_6 are weights, and T_1 to T_6 are the factors. T_1 is the sum of the activity scores in all 30 epochs in a minute, T_2 is the sum of the activity scores in the 8 most active epochs, T_3 is the activity score in the single most active epoch, and T_4 is the sum of the activity scores in the two most active epochs per minute separated by at least 30 seconds. T_5 and T_6 are context factors which are themselves weighted sums of activity in the preceding and following 3 minutes. For example, T_5 may be six times the sum of activity scores in the last minute plus 3 times the sum of activity in the next-to-last minute plus the sum of activity scores in the third-to-last minute:

$$T_5 = T_{1,\,i-3} + 3 * T_{1,i-2} + 6 * T_{1,i-1}, \quad \text{and}$$

$$T_6 = T_{1,i+3} + 3 * T_{1,i+2} + 6 * T_{1,i+1}.$$

(The activity score in each 2-second epoch is transformation 5.) A minute is judged "wake" if $D \geq 1.0$, with scale factors adjusted to the best discriminating point. The maximum percent agreement within this range of scale values is determined over an entire file containing data of over 3000 minutes from the 7 sleep/wake records tested above. The computer then varies the weighting of one term at a time, searching for the combination of weights which produces the highest percent agreement. It is entirely possible that weights of zero will be assigned to some of these factors, or that other factors will be desirable. For example, we hope to add a term for respiration artifact. We are confident that this approach will reveal an optimal technique for recognizing sleep in a minute of activity data.

The implementation of this sleep recognition program is not yet complete. A version of the program in which weights of 0 or 1 were assigned each term factorially has been run, and a maximum percent agreement of 0.93 has been obtained. A listing of this program is included in Appendix 3. Modifications to increase the flexibility of the program are the focus of our efforts for the final two months of this contract year.

Although still a retrospective test and as yet referenced to hand-scoring of activity (not yet EEG), this percent agreement is also extremely encouraging and suggests our efforts will ultimately be comparable to hand-staging. Completion of this program and definition of the staging procedure should be complete as planned by the end of this contract year.

In order to provide a larger data base for testing the sleep recognition program in which careful referencing against EEG scoring is possible, two further sets of programs have been implemented. The first set performs the 240 Hz preprocessing in real time, so that the program can be run during on-going sleep recordings in our laboratory. We are currently accumulating a data base of such recordings which have been both digitized directly from the real-time polygraphic recording and which have also been carefully hand-scored by EEG. The second set of programs collects a data base of hand-staging decisions, plots the sleep stage histogram, and computes sleep stage statistics. Listings of these programs are included in Appendix 4.

A PROTOTYPE DIGITAL ACTIVITY MONITOR

When the 1979-1980 year's contract work was proposed, we believed it would require the full year to develop a working breadboard model of a wearable actigraphic recorder, and a packaged model which could be worn could only be constructed in the 1980-81 year. After extensive negotiations with Mr. Bruce Rule of the Vitalog Corp. we jointly developed a design which could be constructed by them during the 1979-80 year, and which has actually been constructed and checked out in response to our purchase order, although we have not yet received delivery. This device, based on the IM6100 microprocessor (as planned), will have an 8-channel A/D converter, 500 x 12 bit words of EPROM monitor memory, and 6000+ words of 12-bit RAM memory, accessible by our Apple computer system. Most important, it will be packaged in a wearable form. Thus, by the end of this contract year, we expect to be slightly ahead of plan in our hardware development, because we will have gone from a breadboard to a packaged device. Nevertheless, debugging the packaged configuration and installation of the preprocessing software in the portable microprocessor is not likely to be commenced before the 1980-81 contract year, as had been originally planned.

PLAN FOR 1980-1981 IN BRIEF

In the 1980-81 year, as previously planned, we propose to install our sleep staging software in the portable digital recorder and test, refine, and validate its performance in actual sleep recording. At the end of 1981, we plan to submit a technical definition of requirements for a microminiaturized version which would be suitable for field or combat use.

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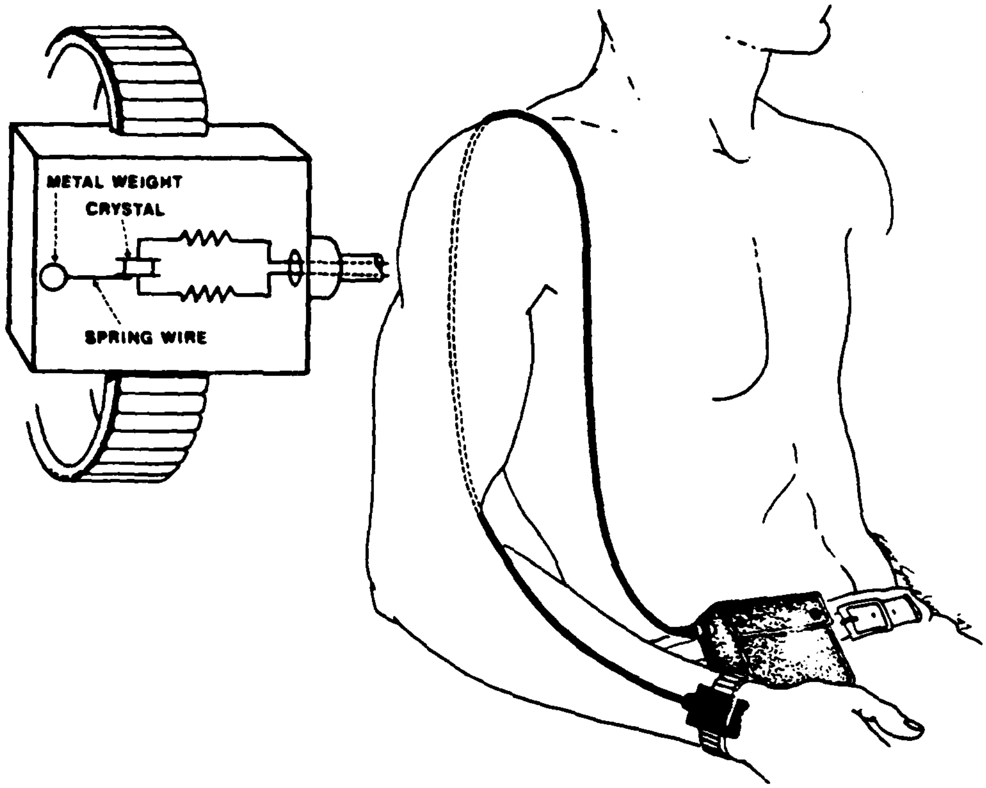

Figure 1. Our current actigraph system, consisting of a piezoelectric crystal transducer connected to a Medilog recorder capable of recording for about 30 hours on a C120 cassette. At left is stylized representation of transducer.

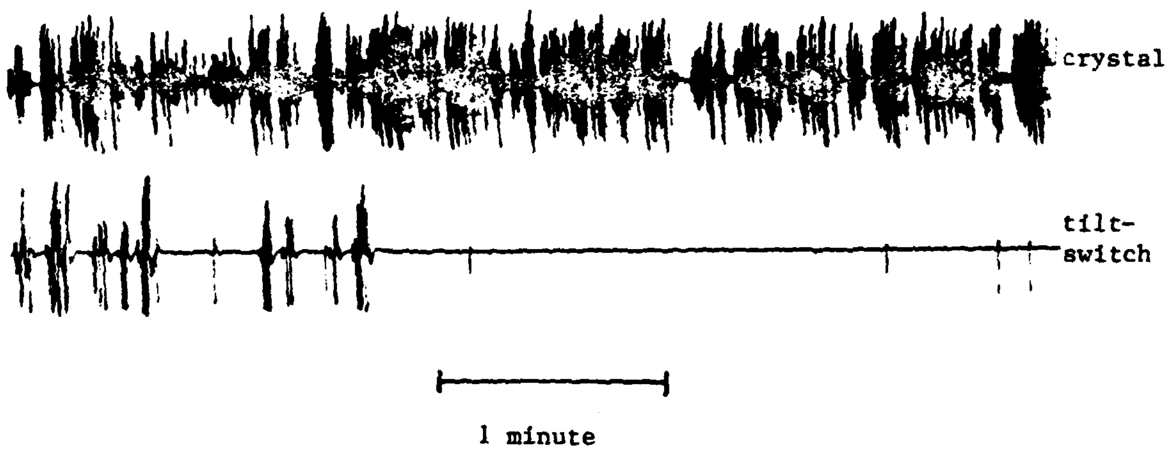

Figure 2. Representative polygraph writeout of activity recorded simultaneously from crystal actigraph (Channel 1, top) and Vitalog tilt-switch activity transducer (Channel 2). Although the crystal measures activity throughout the record, the tilt-switch fails to detect much of this activity.

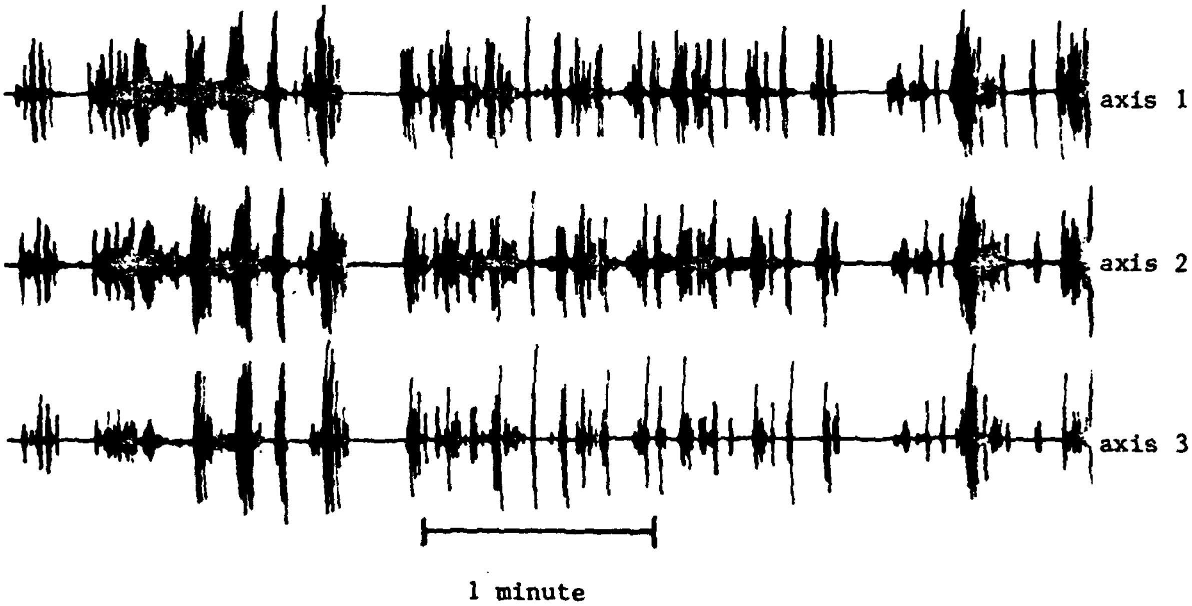

Figure 3. Representative polygraph writeout of 3 crystal actigraphs mounted at the 3 major axes within a single box and worn on the wrist. Although differences in amplitude occur between the 3 channels, there are no failures to detect activity in any channel.

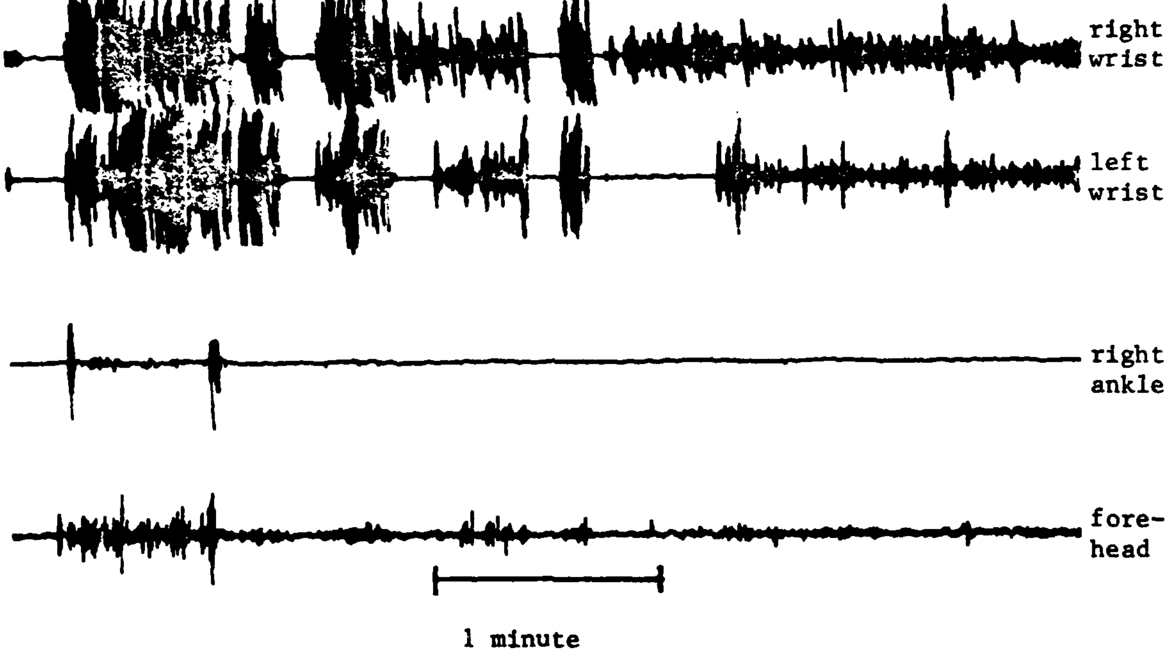

Figure 4. Representative polygraph writeout of activity detected by actigraphs mounted on the right wrist (Channel 1), left wrist (Channel 2), right ankle (Channel 3) and forehead (Channel 4). Bilateral wrist activity frequently occurs in the absence of head or ankle motion.

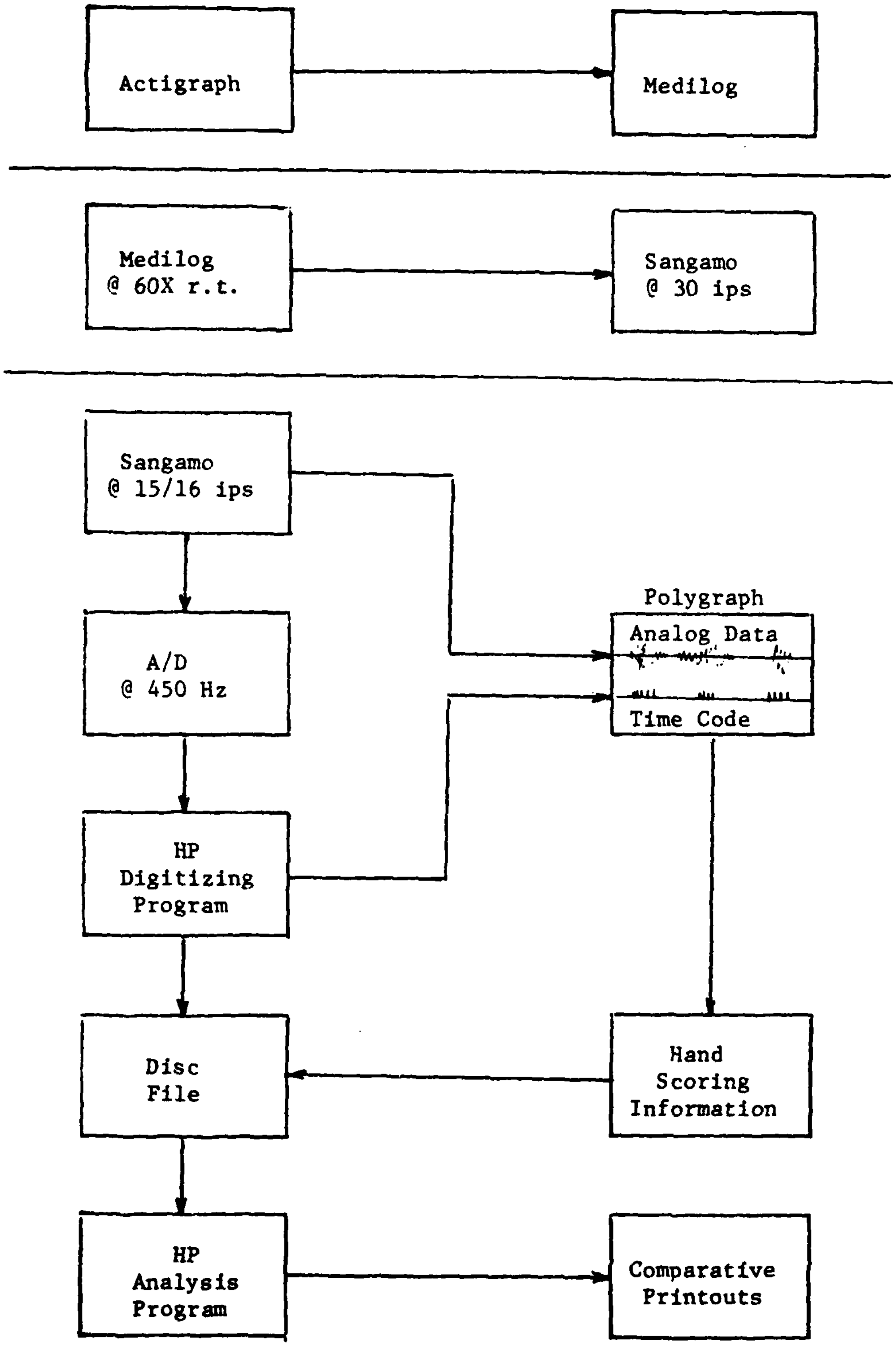

Figure 5. Block diagram illustrating procedure used to determine optimal digital preprocessing algorithm. See text for details.

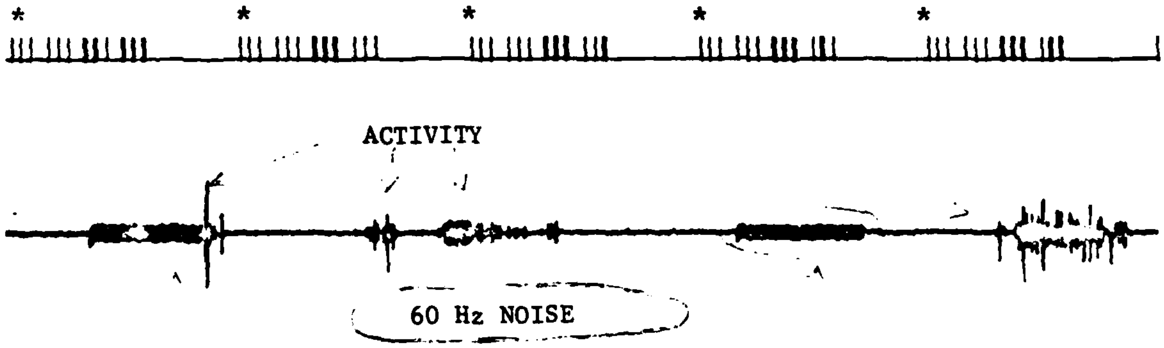

Figure 6a. Polygraph record. Channel 1 is time code. Asterisks indicate beginning of a minute. Channel 2 is analog recording illustrating activity mixed with 60 Hz noise caused by electric blanket.

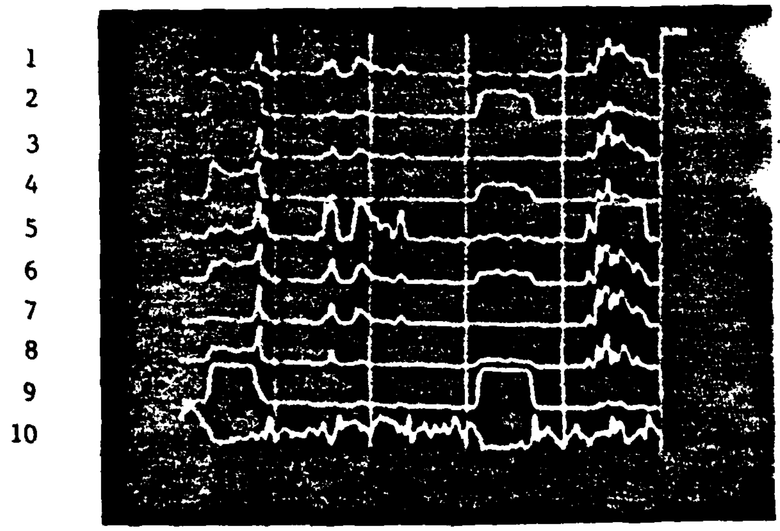

Figure 6b. Photograph of CRT display of 10 digital transformations of the same data. Vertical lines indicate beginning of a minute. Note the absence of noise in traces 1, 3, 5 and 7.

Location	Rating (Best) 1	2	3	(Worst) 4
Left Wrist	9	7	3	0
Right Wrist	9	7	2	1
Forehead	1	4	12	2
Ankle	0	1	2	16

Table 1. Frequency distribution of ratings (or rankings) of activity measured at the left and right wrist, head and ankle. Ratings reflect the relative amount of activity detected from the 4 transducers in each record (n=19).

Table 2. Maximum percent agreement between known sleep/wake status and sleep/wake status computed for each record and each transformation individually.

		Transform Number									
		1	2	3	4	5	6	7	8	9	10
Record Number	1	.85	.87	.86	.89	.90	.90	.89	.90	.90	.83
	2	.91	.93	.92	.93	.93	.93	.93	.93	.93	.85
	3	.77	.82	.81	.84	.87	.85	.84	.83	.83	.79
	4	.92	.96	.94	.94	.94	.95	.95	.94	.96	.83
	5	.83	.83	.83	.84	.83	.84	.84	.84	.85	.78
	6	.96	.97	.96	.97	.97	.97	.97	.97	.95	.89
	7	.91	.89	.91	.88	.91	.90	.91	.89	.87	.80
Mean		.88	.90	.89	.90	.91	.91	.90	.90	.90	.82
Median		.91	.89	.91	.89	.91	.90	.91	.90	.90	.83

Table 3. Rank ordering of percent agreement scores (Table 2) within each record.

		Transform Number									
		1	2	3	4	5	6	7	8	9	10
Record Number	1	9	7	8	6	1	3	5	3	1	10
	2	9	1	8	5	4	1	7	5	3	10
	3	10	7	8	4	1	2	3	5	5	9
	4	9	1	8	6	5	3	4	6	1	10
	5	9	7	7	4	6	2	4	2	1	10
	6	8	3	7	3	1	2	3	3	9	10
	7	1	7	1	8	1	5	4	6	9	10
Mean		7.9	4.7	6.7	5.1	2.7	2.6	4.3	4.3	4.1	9.9
Median		9	7	8	5	1	2	4	5	3	10

Table 4. Maximum percent agreement between known sleep/wake status and sleep/wake status computed for each transformation with all records taken together.

		Transform Number						
		3	4	5	6	7	8	9
	1	.75	.84	.74	.82	.66	.85	.80
	2	.89	.90	.91	.90	.90	.90	.90
Record	3	.72	.75	.84	.76	.78	.75	.71
	4	.91	.93	.94	.92	.92	.93	.94
Number	5	.74	.74	.56	.71	.56	.74	.83
	6	.96	.96	.97	.96	.95	.96	.94
	7	.90	.88	.91	.88	.91	.88	.87
	Mean	.84	.86	.84	.85	.81	.86	.86
	Median	.89	.88	.91	.88	.90	.88	.87

Table 5. Rank ordering of percent agreement scores (Table 4) within each record for all records taken together.

		Transform Number						
		3	4	5	6	7	8	9
	1	5	2	6	3	7	1	4
	2	7	2	1	2	2	2	2
Record	3	6	5	1	3	2	4	7
	4	7	3	1	5	5	3	1
Number	5	2	2	6	5	6	2	1
	6	2	2	1	2	6	2	7
	7	3	4	1	4	1	4	7
	Mean	4.6	2.9	2.4	3.4	6.6	2.6	4.1
	Median	5	2	1	3	5	2	4

APPENDIX 1

$D5610 T=00004 IS ON CR00011 USING 00014 BLKS R=0132

```
FTN4,L
      PROGRAM D5610,3
C
C-----LAST ALTERED: 12/13/79
C
C-----ACTIGRAPH DIGITIZER (PART 2)
C
C---THIS PRGM DIRECTS THE CONVERSION OF ANALOG
C--ACTIVITY DATA INTO 10 DIGITAL TRANSFORMATIONS
C--WHICH ARE STORED ON DISC. "D5610" IS CALLED
C--FROM "C5610", AND BEGINS DUMPING DATA AT
C--SECTOR 4 OF TRACK SPECIFIED IN CALLING PRGM. (JBW)
C
      INTEGER BUFFER(512),IOUT(256),RMP(5),SECTOR,TRACK
      INTEGER DFSCR,FLAG,XCDSMA,XCDSMB
      INTEGER SUMA,SUMB,SUMASQ,SUMBSQ
      INTEGER SUMAPL(11),SUMBPL(11),SMA2PL(11),SMB2PL(11)
      INTEGER SUMADF,SUMBDF,SMA2DF,SMB2DF
      DATA IAPOOL,IBPOOL,I3POOL,I4POOL/4*0/
      DATA SUMAPL,SUMBPL,SMA2PL,SMB2PL/44*0/
C
C  GET START TRACK FROM RMPAR
C
      CALL RMPAR(RMP)
      ISTART=RMP
      TRACK=ISTART
      ITRACK=TRACK
      KPTS=1
      SECTOR=4
C
C  READ IN 1 EPOCH OF DATA
C
      FLAG=-1
      LL = 11
      CALL DMA1J(BUFFER,FLAG)
   10 IF (TRACK.GT.190) GO TO 10001
9     IF(ISSW(0)) 1001,8
8     IF(FLAG) 9,12
12    IPTR=FLAG
      FLAG=-1
C
C  INITIALIZE THE SUMS FOR THIS EPOCH
C
11    SUMA=0
      SUMB=0
      SUMASQ=0
      SUMBSQ=0
      SUMADF=0
      SUMBDF=0
      SMA2DF=0
      SMB2DF=0
```

```
      ISMAMX=0
      ISMBMX=0
C
C  COMPUTE THE SUMS OVER THE LAST EPOCH
C
      DO 100 J = 1,240,2
      IB=BUFFER(J+IPTR)
      IA=BUFFER(J+IPTR+1)
      CALL JSHFT(IA,IB,IA2,IB2)
      IF (SUMA+IA.LT.0) GO TO 20
      SUMA=SUMA+IA
      GO TO 25
   20 SUMA=32767
   25 IF (SUMB+IB.LT.0) GO TO 30
      SUMB=SUMB+IB
      GO TO 35
   30 SUMB=32767
   35 IF (SUMASQ+IA2.LT.0) GO TO 40
      SUMASQ=SUMASQ+IA2
      GO TO 45
   40 SUMASQ=32767
   45 IF (SUMBSQ+IB2.LT.0) GO TO 50
      SUMBSQ=SUMBSQ+IB2
      GO TO 55
   50 SUMBSQ=32767
   55 CONTINUE
C
C  COMPUTE J+5 MODULO 11
C
      LL = LL - LL/11*11 + 1
      MM = LL + 4
      MM = MM - MM/11*11 + 1
      IF(ISMAMX.LT.IA) ISMAMX=IA
      IF(ISMBMX.LT.IB) ISMMX=IB
C
C  COMPUTE DIFFERENCE SCORES
C
      IQ=DFSCR(IA,LL,SUMAPL,IAPOOL,MM)
      IF (SUMADF+IQ.LT.0) GO TO 60
      SUMADF=SUMADF+IQ
      GO TO 65
   60 SUMADF=32767
   65 IQ=DFSCR(IB,LL,SUMBPL,IBPOOL,MM)
      IF (SUMBDF+IQ.LT.0) GO TO 70
      SUMBDF=SUMBDF+IQ
      GO TO 75
   70 SUMBDF=32767
   75 IQ=DFSCR(IA2,LL,SMA2PL,I3POOL,MM)
      IF (SMA2DF+IQ.LT.0) GO TO 80
      SMA2DF=SMA2DF+IQ
      GO TO 85
   80 SMA2DF=32767
   85 IQ=DFSCR(IB2,LL,SMB2PL,I4POOL,MM)
      IF (SMB2DF+IQ.LT.0) GO TO 90
```

```
      SMB2DF=SMB2DF+IQ
      GO TO 100
   90 SMB2DF=32767
100     CONTINUE
C
C  COUNT THE PEAKS
C
        XCDSMA=0.9*ISMAMX
        XCDSMB=0.9*ISMBMX
        NCTA=0
        NCTB=0
        DO 200 J=1,240,2
        IA=BUFFER(J+IPTR)
        IB=BUFFER(J+IPTR+1)
        IF(IA.GE.XCDSMA) NCTA=NCTA+1
        IF(IB.GE.XCDSMB) NCTB=NCTB+1
200     CONTINUE
C
C  FILL THE OUTPUT BUFFERS
C
        L=KPTS
        IOUT(L)=SUMA
        IOUT(L+1)=SUMB
        IOUT(L+2)=SUMASQ
        IOUT(L+3)=SUMBSQ
        IOUT(L+4)=SUMADF
        IOUT(L+5)=SUMBDF
        IOUT(L+6)=SMA2DF
        IOUT(L+7)=SMB2DF
        IOUT(L+8)=NCTA
        IOUT(L+9)=NCTB
        KPTS=KPTS+10
        IF(KPTS.LT.250) GO TO 1000
C
C  WE'RE READY TO WRITE
C
        CALL EXEC(2,2107B,IOUT,256,TRACK,SECTOR)
        KPTS=1
        SECTOR = SECTOR+4
        IF(SECTOR.LT.95)  GO TO 1000
        TRACK=TRACK+1
        SECTOR = 0
 1000 GO TO 10
10001 WRITE (1,10002)
10002 FORMAT (" DISC FULL ")
1001    CALL STP56
        WRITE(1,10010) ITRACK,TRACK,SECTOR
10010   FORMAT("END OF DATA REDUCTION AND TRANSFER"/
     1," DATA ORIGIN","  TRACK :",I8/,
     2" AND CONCLUSION  TRACK :",I8," SECTOR :",I8)
C
C
C
        STOP
```

```
0160          END
0161          END$
```

$DMA1J T=00004 IS ON CR00011 USING 00034 BLKS R=0347

```
ASMB,L,R
      NAM DMA1J,3
*** THIS PRGM READS A/D THRU DMA1, ACCUMULATES
* SUMS & SUMS OF SQUARES, GENERATES TIME CODE,ETC
* MODIFIED BY JBW 11/26/79
       ENT P5610,DMA1J,BUFFR
       ENT STP56
       EXT $LIBR,$LIBX,.ENTR,JP561
BUFFR  NOP
FLAG   NOP
DMA1J  NOP
       JSB .ENTR
       DEF BUFFR
       JSB $LIBR
       NOP
       LDA DMA1J
       STA SVALV
       CLF 0
       CLC 7B
       LDA JP561
       STA 6B
       LDA DMA1J
       STA P5610
       LDA BUFFR
       STA PTBF
       CLA
       STA 10B
       LDA CW1
       OTA 6B
       CLC 2B
       LDA DBUF
       IOR =B100000
       OTA 2B
       STC 2B
       LDA CW3
        OTA 2B
       LDA MODE
       OTA SC
       STC SC,C
       STC 6B,C
       LDA CLC6,I
       STA CLSAV
       LDA STC6,I
       STA STSAV
       CLA
       STA CLC6,I
       STA STC6,I
       LDB INTBA
       INB
       LDA 1,I
       SZA
       STC 7B
```

```
      LDA STF0
      STA XXLNK
      LDA STC
      STA XXLNK+1
      LDA =B124774
      STA XXLNK+2
      JSB $LIBX
      DEF P5610
P5610 NOP
      CLF 0
      CLF 6
      CLC 6B
      STA XA
      STB XB
      ERA,ALS
      SOC
      INA
      STA XEO
*
*  ALLOW PRIVILEGED INTERRUPTS WITH THIS DRIVER
*
      LDA MPTFL  SAVE STATE OF MP ON ENTRY
      STA MPFSV
      INA MPTFL  INDICATE TO ALL OTHERS MP OFF
      STA MPTFL
      STC 12B    ENABLE PRIVILEGED INTERRUPTS
      STF 12B
      CLC 7B     DISABLE DMA CH2
      CLC 10B,C  CLEAR FLAG ON 5610 IF ANY
      STF 00B    ALLOW OTHERS THEIR CHANCE
      LDA CW1
      OTA 6B
      CLC 2B
      LIA 01B
      SLA
      JMP HALT
      IOR =B4
      OTA 01B
      LDA DBUF
GO    IOR =B100000
      OTA 2B
      STC 2B
      JSB RESET   RESTART DMA+5610
      JSB CHECK   HAVE WE MADE OURSELVES RE-ENTRANT?
      LIA 01B  ELSE SIGNAL HERE
      IOR =B10
      OTA 01B
*
* PROCESS INPUT FROM A/D
*
      CLA     ZERO SUMA & SUMB
      STA SUMA
      STA SUMB
      LDA DBUF  INIT. PNTR FOR INPUT BUF
```

```
      STA PTR
      LDA =D-4  SET UP CNTR TO SUM 4 VAL.S
      STA CTR
L.XX  LDA PTR,I  GET VAL. FROM BUF (X)
      CLB
      SSA          IS X NEG?
      JMP XNEG
      LSR 6        NO, SHIFT 6 BITS OF JUNK
      JMP AHEAD    AND JUMP AHEAD
XNEG  CMA,INA      YES, MAKE POS.,
      LSR 6        THEN SHIFT 6 BITS
      CMA,INA      THEN NEGATE AGAIN
AHEAD LDB 0
      ADA SUMA
      STA SUMA   ADD X TO SUMA
      LDA 1
      MPY 0  SQUARE X & TRUNCATE TO 9 BITS
      LSR 9
      ADA SUMB   ADD X-SQ TO SUMB
      STA SUMB
      ISZ PTR
      ISZ CTR   HAVE WE DONE 4 RPTS?
      JMP L.XX  NO, LOOP BACK
      STA PTBF,I   YES, PACK SUMB IN OUT BUF
      ISZ PTBF
      LDA SUMA     PACK SUMA IN NEXT BUF LOC
      STA PTBF,I
      ISZ PTBF
      CLA
      ISZ EPOCH  HAVE WE DONE AN EPOCH YET?
      JMP GTM      NO, EXIT
*
*  AN EPOCH HAS BEEN ACCUMULATED IF HERE
*
      LDA FLAG,I
      SSA,RSS    DATA RATE EXCESSIVE
      JMP HALT   IF BRANCH TAKEN
      LDA OR
      XOR MASK
      STA MASK    OUT BUF READY TO WRITE
      STA FLAG,I
      XOR OR      SWITCH TO THE NEXT OUT BUF
      ADA BUFFR
      STA PTBF
      LDA =D-120 SET UP FOR ANOTHER EPOCH
      STA EPOCH
*
*  SET UP TIME CODE PULSE TRAIN
*
      ISZ PM30   COUNT 30 EPOCHS BEFORE
      JMP GTM    INCREMENTING TIME CODE
      LDA =D-30  REPRESENTING MINUTES
      STA PM30   IN REAL TIME
      LDA XBITS
```

```
      STA GOFLG
      LDA =D-3
      STA OCNT
      LIA 01B
      AND =B17
      LDB TCTR
      BLF
      IOR 1
      AND =B77777
      OTA 01B   SET THE COUNT FOR ALL TO SEE
      LDA TCTR
      INA
      STA TCTR
      ALF
      STA OTWRD  SAVE IN TEMP STORAGE
      JMP GOP11
GTM   CLA
      ISZ DELAY   COUNT TO 40
      JMP ZERO     BEFORE SENDING
      LDA =D-40   TIME CODE BIT
      STA DELAY   TO RELAY
      LDA GOFLG   JUMP OUT IF
      SSA,RSS     ALL BITS HAVE
      JMP GO1     BEEN SENT.
      LDA TCNT    INCREMENT SEQUENCER
      INA         AND EVALUATE
      STA TCNT
      SSA,RSS
      JMP NZERO
      CLA         MINUS: SEND A ZERO
      JMP ZERO
NZERO SZA,RSS      ZERO: SEND DATA
      JMP NTWO
      LDB =D-3     ONE: SEND A ONE &
      STB TCNT     RESET SEQUENCER
      ISZ GOFLG
      NOP
      JMP ZERO
NTWO  ISZ OCNT     LEAVE A GAP BETWEEN
      JMP NONE     EACH OCTAL DIGIT
      LDA =D-4
      STA OCNT
      LDA =D-3
      STA TCNT
      CLA
      JMP ZERO
NONE  LDA OTWRD
GOP11 RAL
      STA OTWRD
ZERO  AND =B1   SAVE ONLY ONE BIT OF THE WORD
      LIB MICRO    GET CURRENT RELAY STATUS
      SWP          EXCHANGE A,B REGISTERS
      AND =B177770 SAVE ALL BUT TOGGLE BIT
      IOR B        RECONSTRUCT AND
```

```
      OTA MICRO     LOAD REGISTERS ON RELAY CARD
      STC MICRO,C   NOW LATCH REGISTERS
       JMP GO1      NOW EXIT
*
DELAY  DEC -40
PM30   DEC -30  30 EPOCHS PER MINUTE CNTR
XBITS  DEC -11  12 BITS TO BE OUTPUT
TCNT   DEC -3
OCNT   DEC -3
TCTR   OCT 4000  TIME PULSE COUNT;
OTWRD  NOP  TEMPORARY STORAGE FOR TIME CODE
GOFLG  NOP  FLAG TO INDICATE NO. OF BITS LEFT
MICRO  EQU 21B  RELAY CARD I/O SLOT ADDRSS
B     EQU 1          B REGISTER
A     EQU 0          A REGISTER
GO1    LDA CW3     LOAD COUNT FOR DATA INPUT
       OTA 2B
       LDA MODE
       OTA SC
       STC SC,C
       STC 6B,C
OUT    CLF 00B   PREPARE FOR EXIT
       CLA
       STA TFLAG
       LDA MPFSV RESTORE STATE OF MEMORY
       STA MPTFL PROTECT TO WHAT IT WAS ON ENTRY
       SZA,RSS
       JMP POUT  IT WAS ON
       LDB XB
       LDA XEO
       CLO
       SLA,ERA
       STF 1B
       LDA XA
       STF 0
       JMP P5610,I
POUT  LDA P5610
       STA XLINK
       CLC 12B  ALLOW ALL INTERRUPTS AGAIN
       STF 12B  PREPARE FOR NEXT TIME AND $CIC
       DLD INTBA,I  EXAMINE INTERRUPT TABLES
       SSB       SKIP IF BUSY BIT NOT ON
       STC 07B  OTHERWISE, ALLOW DMA CH2 TO INTERRUPT
*
*  THE ABOVE CODE IS NEARLY IDENTICAL TO THAT IN
*   $IRT AND $CIC
*
       LDB XB
       LDA XEO
       CLO
       SLA,ERA
       STF 1B
       LDA XA
       JMP XLINK+1
```

```
PTBF   OCT 0    POINT TO THE USER OUT BUFFER AREA
DBUF   DEF DMA1J  USE THE CODE FOR A BUFFER!!!!!
SUMA   OCT 0
SUMB   OCT 0
CTR    OCT 0
PTR    NOP
SC     EQU 10B
STFO   STF 0B
XLINK  EQU 774B
XXLNK  EQU 775B
XA     OCT 0
XB     NOP
XEO    NOP
MPFSV  NOP    TEMPORARY REGISTER FOR FLAG(MP)
EPOCH  DEC -120
MASK   DEC 256
OR     DEC 256
MPTFL  EQU 1770B
CW1    OCT 120010
CW3    DEC -4
CLC6   OCT 003531    MODIFIED BY GW,7 78
STC6   OCT 003667    MODIFIED BY GW, 7 78
STSAV  OCT 0
CLSAV  OCT 0
MODE   OCT 10000
INTBA  EQU 1654B
STF    STF 0B
STC    STC 5B
*
HALT   CLC 06B,C
       LIA 01B
       IOR =B2
       OTA 01B
       JMP OUT
STP56  NOP
*
*
*  THIS ROUTINE MUST BE ENTERED WHEN THROUGH
*  WITH THE 5610 OR ELSE YOU'LL BE SORRY.
*
*
       ISZ STP56
       JSB $LIBR
       NOP
       CLC 06B,C  STOP
       CLA
       OTA 01B     CLEAR DISPLAY REGISTER
       STA 06B   PREVENT ANY MORE INTERRUPTS
       JSB $LIBX  RETURN TO NORMAL
       DEF STP56 AND TO THE USER
*
*
*  RESTART DMA & 5610 A/D HERE
*
```

```
*
RESET  NOP
       LDA CW3
       OTA 02B  LOAD NEGATIVE COUNT WORD
       LDA MODE SET CONTROL ON 5610
       OTA SC
       STC SC,C   SET CONTROL LINE LOGIC
       STC 06B,C   RESTART DMA
       JMP RESET,I  DONE!
*
*
*
*
*
*
BAD    CLC 06B,C  STOP,STOP,STOP!
       LDA SVALV  LOCATE LAST GOOD LINK
       STA P5610
       CLC 10B,C
       LDA =B777  SIGNAL WE'RE OUT OOF LUCK
       OTA 01B    SET SWITCH PANEL
       JMP GO1    TRY IT AND HOPE FOR THE BEST
*
*
*  HERE MAKE SURE WE HAVE'NT INTERRUPTED OURSELVES
*
*
*
CHECK  NOP
       LDA TFLAG  IF ZERO, WE'RE IN LUCK
       SZA
       JMP BAD     TOO BAD!
       INA
       STA TFLAG
       LDA P5610   SAVE THE GOOD LINK
       STA SVALV
       JMP CHECK,I  NOW WE HAVE A SAFETY VALVE
SVALV  NOP
TFLAG  NOP
       END
```

```
$DFSCR T=00004 IS ON CR00011 USING 00004 BLKS R=0000

ASMB,L,R
        NAM DFSCR,3
        ENT DFSCR
        EXT .ENTR
XJ      NOP
J       NOP
SUM     NOP
SMPL    NOP
K       NOP
DFSCR   NOP
        JSB .ENTR
        DEF XJ
        LDA XJ,I
        LDB SMPL,I
        ADA 1      SMPL=SMPL+XJ
        LDB K,I
        ADB SUM    ADDRESS OF SUM(K)
        ADB =D-1
        CMA,INA
        ADA 1,I    -SMPL+SUM(K)
        CMA,INA
        STA SMPL,I
        LDA XJ,I    SUM(K)<- XJ
        STA 1,I
        LDA J,I
        ADA =D-1
*  XK <- SUM(J)
        ADA SUM  A(SUM(J)) -> A
        LDA 0,I  A<-SUM(J)
        MPY =D11  XK*11
        CMA,INA
        ADA SMPL,I  -XK*11+SMPL
        SSA          TAKE ABSOLUTE VALUE
        CMA,INA
        JMP DFSCR,I  RETURN
        END
```

APPENDIX 2

?JSRCH T=00004 IS ON CR00011 USING 00023 BLKS R=0200

```
FTN4,L
      PROGRAM JSRCH,3
C-------------------------------------------------------------
C     2/7/80
C
C     "JSRCH" EVALUATES CRITERIA FOR RECOGNIZING
C  SLEEP FROM DIGITIZED ACTIVITY DATA. RECORD
C  HAS BEEN SCORED VISUALLY & SLEEP PERIODS
C  ARE IDENTIFIED ON DISK (USING "SCORE"
C  PROGRAM).    JBW
C
C     CALL IS: *"ON,SLEEP,ST,LT,LS,AL" WHERE 'ST' IS
C  START TRACK, 'LT' & 'LS' ARE LAST TRACK & SECTOR
C  AND 'AL' IS STARTING ALGORITHM #
C
C  NOTE: "STOP 6666" MEANS RECORD HAS NOT
C  BEEN SCORED. RUN "SCORE", THEN TRY AGAIN
C  "STOP 7777" IS NORMAL TERMINATION
C-------------------------------------------------------------
      DIMENSION NBUF(3072),IBUF(256),FPO(4),IPRM(5)
      EQUIVALENCE (IPRM,IT1),(IPRM(2),IT2),(IPRM(3),IS2)
      EQUIVALENCE (IPRM(4),ITR),(IPRM(5),IC)
      CALL RMPAR(IPRM)
C----------
C  CHECK FOR CORRECT DISC
C----------
      CALL EXEC(1,113B,IBUF,256,0,0)
      IF (IBUF(2).NE.3828) STOP 1111
C----------
C  SET UP FIRST PASS: INTERPRET SCORED D5610-FORMAT
C  DATA & STORE IN TEMPORARY SCRATCH-PAD AREA
C  REPEAT FOR EACH ALGORITHM
C----------
      IF (ITR.EQ.0) GO TO 100
      ITR=ITR-1
  100 ITR=ITR+1
      SMAX=0.
      NS=(IT2-IT1)*96+IS2-4
      IT=IT1
      IS=4
      KEP=0
      IMAX=0
      IMIN=32767
      NTR=1
      NSEC=0
      JSLP=0
      SLPN=0.
C----------
C  READ D5610 DATA 4 SECTORS AT A TIME
C----------
```

```
      DO 800 I=1,NS,4
      CALL EXEC(1,113B,IBUF,256,IT,IS)
      IS=IS+4
      IF (IS.LT.95) GO TO 700
      IT=IT+1
      IS=0
C----------
C  MAKE SURE DATA IS SCORED
C----------
  700 IF (IBUF(256).EQ.9999) GO TO 750
      WRITE (4,720)
  720 FORMAT (" RECORD HAS NOT BEEN SCORED")
      STOP 6666
C----------
C  DETERMINE RANGE OF ACTIVITY SCORES
C----------
  750 DO 800 J=ITR,ITR+240,10
      IMIN=MINO(IMIN,IBUF(J))
      IMAX=MAXO(IMAX,IBUF(J))
C----------
C  COMPRESS DATA & PLACE IN SCRATCH-PAD AREA
C----------
      KEP=KEP+1
      NBUF(KEP)=IBUF(J)
      IF (MOD(KEP,30).NE.0) GO TO 800
C----------
C  TRANSFER SLEEP/WAKE SCORE TO END OF SCRATCH-PAD
C----------
      NBUF(2971+KEP/30)=IBUF(251+(J-1)/50)
C----------
C  SUM MINS OF SLEEP & TOTAL MINS
C----------
      JSLP=JSLP+IBUF(251+(J-1)/50)
      SLPN=SLPN+1.
      IF (KEP.LT.2970) GO TO 800
C----------
C  WRITE WHEN BUFFER FULL
C----------
      CALL EXEC(2,2113B,NBUF,3072,NTR,NSEC)
C----------
C  REINITIALIZE & UPDATE FOR NEXT BUFFER
C----------
      KEP=0
      DO 790 M=1,3072
  790 NBUF(M)=-1
      NSEC=NSEC+48
      IF (NSEC.LT.95) GO TO 800
      NTR=NTR+1
      NSEC=0
  800 CONTINUE
C----------
C  END FIRST PASS: PRINT SUMMARY
C----------
      PSLP=JSLP/SLPN
```

```
      WRITE (6,1060) IT1,IT2,IS2,ITR,IMIN,IMAX,PSLP,SLPN
 1060 FORMAT (1H1/" START: TRACK "I3" SECTOR  0"/
     -" STOP:  TRACK "I3" SECTOR "I2/
     -" TRANSFORM#"I3/" MIN ="I6/
     -" MAX ="I6/" % SLEEP ="F4.3/
     -" # MINUTES SCORED ="F5.0/)
      WRITE (6,1070)
C----------
C  SET UP SECOND PASS:
C----------
      NSECS=NSEC+(NTR-1)*96
 1080 WRITE (4,1085)
 1085 FORMAT (" ENTER E/M CRIT., INIT. CRIT.,
     -TERM. CRIT., & STEP SIZE")
      READ (4,*) IC,CPR,CPS,CSTEP
      IF (IC.EQ.99) GO TO 1700
      IF (IC.LT.0) GO TO 2000
      ICR=IC
      WRITE (4,1070)
 1070 FORMAT (/14X"% CORR"6X"CRIT"3X"E/M"5X"'W'/W"
     -5X"'W'/S"5X"'S'/W"5X"'S'/S"/)
      KSEQ=1
      PMAX=0.
 1090 NTR=1
      NSEC=0
      MDV=0
      PO=0.
      NEP=0
      DO 1092 I=1,4
 1092 FPO(I)=0.
C----------
C  READ DATA FROM SCRATCH-PAD
C----------
      DO 1099 I=1,NSECS,48
      CALL EXEC(1,113B,NBUF,3072,NTR,NSEC)
      NSEC=NSEC+48
      IF (NSEC.LT.95) GO TO 1095
      NTR=NTR+1
      NSEC=0
C----------
C  SET CRITERION & COUNT NUMBER OF EPOCHS
C  PER MINUTE EXCEEDING CRITERION
C----------
 1095 DO 1099 J=1,2970
      IF (NBUF(J).EQ.-1) GO TO 1099
      MDV=MDV+1
      IF (FLOAT(NBUF(J)-IMIN).GE.(IMAX-IMIN)*CPR) NEP=NEP+1
      IF (MDV.LT.30) GO TO 1099
C----------
C  DETERMINE TRUE SLEEP OR WAKE FOR THIS MIN.
C----------
      KS=NBUF(2971+J/30)
C----------
C  COMPUTE ESTIMATE OF SLEEP OR WAKE
```

```
C  FOR THIS MIN.
C----------
      LS=2
      IF (NEP.GE.ICR) LS=0
C----------
C  UPDATE CONTINGENCY ARRAY
C----------
 1098 FPO(KS+LS+1)=FPO(KS+LS+1)+1.
      PO=PO+1.
      NEP=0
      MDV=0
 1099 CONTINUE
C----------
C  COMPUTE PERCENT CORRECT & DISPLAY RESULTS
C----------
 1100 PC=(FPO(1)+FPO(4))/PO
      DO 1150 I=1,4
 1150 FPO(I)=FPO(I)/PO
      GO TO (1160,1170),KSEQ
 1160 WRITE (4,1200) PC,CPR,ICR,(FPO(I),I=1,4)
      GO TO 1250
 1170 WRITE (6,1200) PC,CPR,ICR,(FPO(I),I=1,4)
      GO TO 1080
 1200 FORMAT (10X,2F10.4,I6,4F10.4)
 1250 SMAX=AMAX1(SMAX,PC)
      PMAX=AMAX1(PMAX,PC)
      IF (PMAX.EQ.PC) CPMEM=CPR
      CPR=CPR+CSTEP
      IF (CPR.LE.CPS) GO TO 1090
      GO TO 1080
C----------
C  PRINT MAX PC
C----------
 1700 KSEQ=KSEQ+1
      CPR=CPMEM
      GO TO 1090
 2000 WRITE (6,2500) ITR,SMAX
 2500 FORMAT (//15X" OVERALL MAX % CORRECT FOR
     - TRANSFORM# "I2" = "F5.4)
      STOP 7777
      END
      END$
```

APPENDIX 3

?POLLY T=00004 IS ON CR00011 USING 00021 BLKS R=0186

```
FTN4,L
      PROGRAM POLY1,3
C--------------------------------------------------
C  3/27/80
C
C  "POLY1" READS ANY NUMBER OF PACKED ACTIVITY
C  RECORDS & CALCULATES A SERIES OF TERMS REPRESENTING
C  POTENTIAL DISCRIMINATORS BETWEEN SLEEP & WAKE.
C  THESE TERMS ARE WEIGHTED & COMBINED TO YIELD
C  A DECISION (SLEEP OR WAKE) & COMPARED TO KNOWN
C  SLEEP/WAKE STATUS.                          JBW
C
C  CALL IS: (*)ON,POLY1,TR,SEC,NF
C  WHERE 'TR' & 'SEC' ARE STARTING TRACK & SECTOR
C  REFERENCES & 'NF' IS THE NUMBER OF FILES TO BE
C  READ (0 IF ALL)
C--------------------------------------------------
      DIMENSION NBUF(3072),IPRM(5),IPO(100,4),HIST(5,7),C(6),W(6)
      INTEGER A2,A3(8),IFLG,EPOCH(30)
      DATA C/6*1./
      CALL RMPAR(IPRM)
      IT=IPRM
      IS=IPRM(2)
      NF=IPRM(3)
      IF (IT.LT.20) IT=20
      IF (NF.EQ.0) NF=1000
      IFLG=0
      ICC=0
C----------
C  ENTER PARAMETERS
C----------
   40 WRITE (4,50)
   50 FORMAT (/" ENTER WEIGHTS FOR CONTEXT")
      READ (4,*) (W(I),I=1,6)
   60 SCLO=0.
      SCLIM=1.
      STEP=.01
      PMAX=0.
      SMAX=0.
C----------
C  ANALYZE DATA FILE WITH EACH SCALE VALUE
C----------
   75 NTR=IT
      NSEC=IS
      NFILE=0
      MNSLP=0
      TOTMN=0.
      DO 78 I=1,100
      DO 78 J=1,4
   78 IPO(I,J)=0
   80 NFILE=NFILE+1
      MINIT=0
```

```
      MDV=0
C----------
C  READ A BLOCK OF 48 SECTORS
C  INTO CORE & SET UP FOR NEXT BLOCK
C----------
  100 CALL EXEC(1,113B,NBUF,3072,NTR,NSEC)
      NSEC=NSEC+48
      IF (NSEC.LT.95) GO TO 120
      NTR=NTR+1
      NSEC=0
C----------
C  BUFFER DATA BY EPOCHS
C----------
  120 DO 200 I=1,2970
      IF (NBUF(I).EQ.-32767) GO TO 400
      IF (NBUF(I).EQ.-1) GO TO 300
      MDV=MDV+1
      EPOCH(MDV)=NBUF(I)
      IF (MDV.LT.30) GO TO 200
      MDV=0
      MINIT=MINIT+1
C----------
C  COMPUTE TERMS BY MINUTES
C----------
      A1=0.
      A2=0
      DO 130 J=1,8
      A3(J)=0
  130 CONTINUE
      DO 185 NMBR=1,30
C----------
C  TERM 1: TOTAL ACTIVITY
C----------
      A1=A1+FLOAT(EPOCH(NMBR))
C---
C  TERM 2: MAXIMAL EPOCH
C----------
      A2=MAX0(A2,EPOCH(NMBR))
C----------
C  TERM 3: SUM OF 8 BEST EPOCHS
C----------
      DO 170 K=1,8
      IF (EPOCH(NMBR).LT.A3(K)) GO TO 170
      DO 160 L=8,K+1,-1
      A3(L)=A3(L-1)
  160 CONTINUE
      A3(K)=EPOCH(NMBR)
      GO TO 180
  170 CONTINUE
  180 A30=0.
      DO 185 K=1,8
      A30=A30+FLOAT(A3(K))
  185 CONTINUE
C----------
```

```
C  TERM 4: SUM OF 2 BEST DISPERSED EPOCHS
C----------
      A4=0.
      DO 190 K=1,15
      DO 190 L=K+15,30
      SUM=FLOAT(EPOCH(K))+FLOAT(EPOCH(L))
      A4=AMAX1(A4,SUM)
  190 CONTINUE
C----------
C  INCREMENT HISTORY ARRAYS
C----------
      DO 195 J=1,5
      DO 195 K=7,2,-1
      HIST(J,K)=HIST(J,K-1)
  195 CONTINUE
C----------
C  UPDATE HISTORY ARRAY
C----------
  196 HIST(1,1)=A1/983010.
      HIST(2,1)=A2/32767.
      HIST(3,1)=A30/262136.
      HIST(4,1)=A4/65534.
      HIST(5,1)=FLOAT(NBUF(2971+I/30))
      IF (MINIT.LT.7) GO TO 200
C----------
C  EVALUATE POLYNOMIAL THRU RANGE OF SCALE VAL.S
C----------
  198 FRWRD=HIST(1,3)*W(3)+HIST(1,2)*W(2)+HIST(1,1)*W(1)
      BKWRD=HIST(1,5)*W(4)+HIST(1,6)*W(5)+HIST(1,7)*W(6)
      SCALE=SCLO+STEP
  199 D=SCALE*(C(1)*HIST(1,4)+C(2)*HIST(2,4)+C(3)*HIST(3,4)
     &+C(4)*HIST(4,4)+C(5)*FRWRD+C(6)*BKWRD)
C----------
C  DECIDE SLEEP OR WAKE
C----------
      LS=2
      IF (D.GE.1.) LS=0
C----------
C  LOOK UP ACTUAL SLEEP OR WAKE
C----------
      KS=IFIX(HIST(5,4))
C----------
C  UPDATE CONTINGENCY ARRAY
C----------
      ISCL=ISCL+1
      IPO(ISCL,KS+LS+1)=IPO(ISCL,KS+LS+1)+1
      SCALE=SCALE+STEP
      IF (ISCL.GE.100) GO TO 1999
      IF (SCALE.LE.SCLIM) GO TO 199
 1999 MNSLP=MNSLP+KS
      TOTMN=TOTMN+1.
      ISLIM=ISCL
      ISCL=0
  200 CONTINUE
```

```
      GO TO 100
  300 IF (NFILE.LT.NF) GO TO 80
C----------
C  FIND MAX. % CORR
C----------
  400 SCALE=SCLO
      DO 450 I=1,ISLIM
      PC=(IPO(I,1)+IPO(I,4))/TOTMN
      PMAX=AMAX1(PMAX,PC)
      IF (PMAX.EQ.PC) SMAX=SCALE
      SCALE=SCALE+STEP
  450 CONTINUE
C----------
C  ADJUST SCALE RANGE & REPT
C----------
      RANGE=SCLIM-SCLO
      SCLO=SMAX-RANGE/20.
      IF (SCLO.LT.0.) SCLO=0.
      SCLIM=SMAX+RANGE/20.
      IF (SCLIM.GT.1.) SCLIM=1.
      STEP=STEP/10.
      IF (STEP.GE.0.00001) GO TO 75
C----------
C  PRINT RESULTS
C----------
      IF (IFLG.GT.0) GO TO 525
      PSLP=MNSLP/TOTMN
      IFLG=1
      WRITE (6,500) NFILE,TOTMN,PSLP
  500 FORMAT (5X"TOTAL RECORDS:"I4,5X"TOTAL MINUTES:"F6.0,
     &5X"% SLEEP:"F6.3//" PERCENT"20X"TERM  WEIGHTS"31X
     &"CONTEXT WEIGHTS"19X
     &"SCALE"/" CORRECT"8X"C1"5X"C2"5X"C3"5X"C4"5X"C5"5X"C6"
     &8X"W1"5X"W2"5X"W3"5X"W4"5X"W5"5X"W6"7X"FACTOR")
  525 WRITE (6,530) PMAX,(C(J),J=1,6),(W(J),J=1,6),SMAX
  530 FORMAT (F8.4,2(3X,6F7.3),5X,F8.6)
C----------
C  ADJUST WEIGHTS & REPT
C----------
      ICC=ICC+1
      IF (ICC.GT.6) GO TO 540
      C(ICC)=0.
      IF (ICC.GT.1) C(ICC-1)=1.
      GO TO 60
  540 WRITE (4,550)
  550 FORMAT (/"MORE?")
      READ (4,*) KKK
      IF (KKK.NE.0) GO TO 40
      STOP
      END
      END$
```

APPENDIX 4

```
$INPUT T=00004 IS ON CR00011 USING 00020 BLKS R=0180

FTN4,L
      PROGRAM INPUT,3
C
C-----LAST ALTERED: 3/28/80
C
C---'INPUT' ACCEPTS ID INFO & 'PAGE & STAGE'
C--DATA FOR STORAGE ON DISC.      JBW
C
C-----CALL IS: "ON,INPUT,TR,SEC,ED", WHERE 'TR'
C--IS TRACK #, 'SEC' IS SECTOR #, & 'ED' INDICATES
C--WHETHER DATA IS TO BE ENTERED (0) OR EDITED (1).
C
      DIMENSION IBUF(1280),IPRM(5)
      EQUIVALENCE (IPRM(1),ITR),(IPRM(2),ISEC),(IPRM(3),IRW)
      CALL RMPAR(IPRM)
C
C--CHECK FOR CORRECT DISC
      CALL EXEC(1,107B,IBUF,1280,0,0)
      IF (IBUF(1).EQ.3881) GO TO 10
      WRITE (4,1020)
 1020 FORMAT (" WRONG DISC")
      STOP 1111
C
C--CHECK FOR VALID SECTOR
   10 IF (MOD(ISEC,24).EQ.0) GO TO 20
      WRITE (4,1040)
 1040 FORMAT (" INVALID SECTOR")
      STOP 2222
C
C--ENTER NEW DATA OR EDIT EXISTING DATA???
   20 IF (IRW.EQ.1) GO TO 300
C
C--NEW DATA ENTRY---
C--CHECK AVAILABILITY OF INDICATED DISC SEGMENT
      CALL EXEC(1,107B,IBUF,1280,ITR,ISEC)
      IF (IBUF(35).NE.3465) GO TO 40
      WRITE (4,1030)
 1030 FORMAT (" DISC SEGMENT FULL"
     -/" ENTER '1' TO ERASE, '0' TO HALT")
C
C--NOT AVAILABLE (ALREADY USED) -
C--WRITE OVER EXISTING DATA???
      READ (4,*) SLOP1
      J=1*SLOP1
      IF (J.NE.0) GO TO 40
C
C--NO, ABORT
```

```
      STOP 3333
C
C--COMPOSE ID RECORD
   40 J=0
      IBUF(35)=3465
   50 WRITE (4,2000)
 2000 FORMAT (" SUBJECT: _")
      READ (4,2010) (IBUF(I),I=1,30)
 2010 FORMAT (30R1)
      WRITE (4,2030)
 2030 FORMAT (" DATE (MO,DA,YR): _")
      READ (4,*) SLOP1,SLOP2,SLOP3
      IBUF(31)=1*SLOP1
      IBUF(32)=1*SLOP2
      IBUF(33)=1*SLOP3
      WRITE (4,2040)
 2040 FORMAT (" SPEED (PAGES/MIN): _")
      READ (4,*) SLOP1
      IBUF(34)=1*SLOP1
      IF (J.NE.0) GO TO 400
C
C--READ 'PAGE & STAGE' DATA
      DO 90 I=65,1408
   90 IBUF(I)=0
      WRITE (4,2020)
 2020 FORMAT (" ENTER STAGE, STOP PAGE, START PAGE, TIME")
      I=0
  100 I=I+1
      IF (I.LT.304) GO TO 200
      WRITE (4,1045)
 1045 FORMAT (" NO MORE ROOM")
      SLOP1=7.
      GO TO 250
  200 SLOP1=0.
      SLOP2=0.
      SLOP3=0.
      SLOP4=0.
      READ (4,*) SLOP1,SLOP2,SLOP3,SLOP4
  250 IBUF(I*4+61)=1*SLOP1
      IBUF(I*4+62)=1*SLOP2
      IBUF(I*4+63)=1*SLOP3
      IF (IBUF(I*4+63).NE.0) MSTOP=IBUF(I*4+63)
      IBUF(I*4+64)=1*SLOP4
      IF (IBUF(I*4+61).EQ.7) GO TO 400
      IF (IBUF(I*4+62).GT.0.AND.MSTOP.LT.0) GO TO 260
      IF (IBUF(I*4+62).GT.MSTOP) GO TO 275
  260 WRITE (4,2045)
 2045 FORMAT (" PAGE # OUT OF SEQUENCE - REENTER")
      GO TO 200
  275 MSTOP=IBUF(I*4+62)
      GO TO 100
  300 CALL EXEC(1,107B,IBUF,1280,ITR,ISEC)
      IF (IBUF(35).EQ.3465) GO TO 400
      WRITE (4,1050)
```

```
 1050 FORMAT (" NO DATA")
      STOP 4444
C
C--DISPLAY ID INFO
  400 WRITE (6,2050) (IBUF(I),I=1,30)
 2050 FORMAT (/" SUBJECT: "30R1)
      WRITE (6,2060) (IBUF(I),I=31,33)
 2060 FORMATS
      WRITE (6,2070) IBUF(34)
 2070 FORMAT (" PAPER SPEED: "I1" PAGES/MIN")
      WRITE (4,2075)
 2075 FORMAT (" CORRECTIONS? (YES=1, NO=0)_")
C
C--CORRECTIONS???
      READ (4,*) SLOP1
      J=1*SLOP1
      IF (J.NE.0) GO TO 50
      I=-1
      IF (IRW.EQ.0) GO TO 450
C
C--NO, DISPLAY 'PAGE & STAGE' DATA
  425 WRITE (4,2078)
 2078 FORMAT (" LIST ENTIRE FILE (-1) OR LINE #:_")
      READ (4,*) SLOP1
      I=1*SLOP1
      IF (I.EQ.0) GO TO 650
  450 WRITE (6,2080)
 2080 FORMAT (/" LINE# STAGE  STOP START  TIME"/)
      J=0
      IF (I)475,500
  475 DO 600 I=1,336
  500 WRITE (6,2090) I,IBUF(I*4+61),IBUF(I*4+62),
     -IBUF(I*4+63),IBUF(I*4+64)
 2090 FORMAT (I5":"4I6)
      IF (IBUF(I*4+61).EQ.7) GO TO 650
      IF (J.NE.0) GO TO 700
      IF (SLOP1.GT.0.) GO TO 425
  600 CONTINUE
C
C--CORRECTIONS???
  650 WRITE (4,2075)
      READ (4,*) SLOP1
      J=1*SLOP1
      IF (J.EQ.0) GO TO 1000
C
C--YES, ENTER CORRECT DATA
  700 WRITE (4,3000)
 3000 FORMAT (" ENTER LINE#, CORRECT DATA")
      WRITE (6,3100)
 3100 FORMAT (/)
      SLOP1=0.
      SLOP2=0.
      SLOP3=0.
      SLOP4=0.
```

```
      SLOP5=0.
      READ (4,*) SLOP1,SLOP2,SLOP3,SLOP4,SLOP5
      I=1*SLOP1
      IF (SLOP2.GE.0.) GO TO 800
      ND=-1*SLOP2
      DO 900 JK=I,304
      DO 900 KK=61,64
      IBUF(JK*4+KK)=IBUF(JK*4+KK+ND*4)
      IF (IBUF(JK*4+61).EQ.7) GO TO 500
  900 CONTINUE
  800 IBUF(I*4+61)=1*SLOP2
      IBUF(I*4+62)=1*SLOP3
      IBUF(I*4+63)=1*SLOP4
      IBUF(I*4+64)=1*SLOP5
      IF (I.NE.0) GO TO 500
C
C--WRITE TO DISC
 1000 CALL EXEC(2,2107B,IBUF,1280,ITR,ISEC)
      WRITE (6,1010) ITR,ISEC
 1010 FORMAT (/" DISC FILE: TRACK "I3" SECTOR "I2)
      STOP 7777
C
      END
      END$
```

```
$STAGE T=00004 IS ON CR00011 USING 00013 BLKS R=0124

FTN4,L
      PROGRAM STAGE,3
C
C-----LAST ALTERED: 2/1/80
C
C--'STAGE' READS 'PAGE & STAGE' DATA FROM DISC
C--AND PLOTS STANDARD SLEEP STAGE CHART ON AJ
C--PRINTER/PLOTTER.               JBW
C
C--CALL IS: "ON,STAGE,TR,SEC" WHERE 'TR' & 'SEC'
C--ARE TRACK & SECTOR # RESPECTIVELY.
C
C
      INTEGER ESCP,ESCA,ESCN,ESCX,ESCW,ESCZ,ESCY
      INTEGER DOT,DASH
      INTEGER STAGE(240),PAGES(240),CHAR
      DIMENSION IPRM(5),IBUF(64)
      EQUIVALENCE (IPRM,ITR),(IPRM(2),ISEC)
      DATA ESCP/15520B/,ESCN/15516B/,ESCA/15501B/
      DATA ESCX/15530B/,ESCW/15527B/,ESCZ/15532B/
      DATA DOT/56B/,DASH/137B/,ESCY/15531B/
      DATA M0/0/,M1/1/,M2/2/,M3/3/,M5/5/
      CALL RMPAR(IPRM)
C
C--CHECK FOR CORRECT DISC
      CALL EXEC(1,107B,IBUF,64,0,0)
      IF (IBUF(1).EQ.3881) GO TO 10
      WRITE (4,3000)
 3000 FORMAT (" WRONG DISC")
      STOP 1111
C
C--CHECK FOR VALID SECTOR
   10 IF (MOD(ISEC,16).EQ.0) GO TO 20
      WRITE (4,3010)
 3010 FORMAT (" WRONG SECTOR")
      STOP 2222
C
C--MAKE SURE THERE IS DATA
   20 CALL EXEC(1,107B,IBUF,64,ITR,ISEC)
      IF (IBUF(35).EQ.3465) GO TO 30
      WRITE (4,3020)
 3020 FORMAT (" NO DATA")
      STOP 3333
C
C--WRITE ID INFO
   30 WRITE (6,2050) (IBUF(I),I=1,30)
 2050 FORMAT (/30X"SUBJECT: "30R1)
      WRITE (6,2060) (IBUF(I),I=31,33)
 2060 FORMAT (30X"DATE: "I2"/"I2"/"I2)
      IPM=IBUF(34)
      WRITE (6,2070) IPM
 2070 FORMAT (30X"PAPER SPEED: "I1" PAGES/MIN")
```

```
      WRITE (6,2080) ITR,ISEC
 2080 FORMAT (30X"DISC FILE: TRACK "I3" SECTOR "I2)
      IPM=IBUF(34)
      LINES=0
      J=0
C
C--FILL DATA ARRAYS
  100 ISEC=ISEC+1
      CALL EXEC(1,107B,IBUF,64,ITR,ISEC)
      DO 200 I=1,64,4
      IF (IBUF(I).EQ.7) GO TO 300
      J=J+1
      STAGE(J)=IBUF(I)
      IF (J.EQ.1) MSTRT=IBUF(I+3)
      IF (IBUF(I+2).NE.0) ISTRT=IBUF(I+2)
      PAGES(J)=IBUF(I+1)-ISTRT
      ISTRT=IBUF(I+1)
      LINES=LINES+PAGES(J)
  200 CONTINUE
      GO TO 100
C
C--PLOT DATA
  300 J=1
      WRITE (6,1999) MSTRT
 1999 FORMAT (30X"START TIME: "I4)
      MINS=MSTRT-1
      NPGS=0
      WRITE (6,2000)
 2000 FORMAT (//62X"STAGE"//30X"TIME"12X"4"5X"3"
     -5X"2"5X"1"4X"REM"3X"MOVE"2X"WAKE"/)
C
C--DETERMINE STAGE FOR EACH PAGE
      DO 1500 I=1,LINES
      IF (STAGE(J).EQ.0) LOC=410
      IF (STAGE(J).EQ.1) LOC=320
      IF (STAGE(J).EQ.2) LOC=290
      IF (STAGE(J).EQ.3) LOC=260
      IF (STAGE(J).EQ.4) LOC=230
      IF (STAGE(J).EQ.5) LOC=350
      IF (STAGE(J).EQ.6) LOC=380
C
C--EXIT IF '7' (EOF)
      IF (STAGE(J).EQ.7) GO TO 1800
C
C--PRINT HOURS
      NPGS=NPGS+1
      IF (MOD(NPGS,IPM).EQ.0) MINS=MINS+1
      IF (MINS-MINS/100*100.EQ.30.AND.MOD(NPGS,IPM).EQ.0) GO TO 50
      IF (MINS-MINS/100*100.NE.60) GO TO 1000
      MINS=MINS+40
      IF (MINS.EQ.2400) MINS=0
  500 WRITE (6,2150) ESCA,M1,M5,M0
      WRITE (6,2100) ESCN
      WRITE (6,2400) MINS
```

```
      WRITE (6,2100) ESCP
      N1=LOCM/100
      N2=MOD(LOCM,100)/10
      N3=MOD(MOD(LOCM,100),10)
      WRITE (6,2150) ESCA,N1,N2,N3
C
C--INITIALIZE PLOT:
C--SEND 'ESC P' TO ENTER PLOT MODE
 1000 IF (I.NE.1) GO TO 1200
      WRITE (6,2100) ESCP
 2100 FORMAT (R2"_")
      GO TO 1250
C
C--DRAW HORIZ LINE IF TRANS BETW STAGES
 1200 IF (LOC-LOCM)1215,1250,1210
C
C--(TO RIGHT)
 1210 WRITE (6,2150) ESCY,M0,M0,M3
      DO 1212 N=LOCM,LOC-1,6
      WRITE (6,2200) ESCX,M0,M0,M3,DASH,ESCX,M0,M0,M3
 1212 CONTINUE
      GO TO 1245
C
C--(TO LEFT)
 1215 WRITE (6,2150) ESCY,M0,M0,M3
      DO 1217 N=LOC,LOCM-1,6
      WRITE (6,2200) ESCW,M0,M0,M3,DASH,ESCW,M0,M0,M3
 1217 CONTINUE
 1245 WRITE (6,2150) ESCZ,M0,M0,M3
C
C--PRINT EXTRA DOT FOR REM
 1250 IF (STAGE(J).NE.5) GO TO 1260
      N1=(LOC-1)/100
      N2=MOD(LOC-1,100)/10
      N3=MOD(MOD(LOC-1,100),10)
      WRITE (6,2125) ESCA,N1,N2,N3,DOT
C
C--PRINT DOT & LF FOR EACH PAGE
 1260 N1=LOC/100
      N2=MOD(LOC,100)/10
      N3=MOD(MOD(LOC,100),10)
      WRITE (6,2200) ESCA,N1,N2,N3,DOT,ESCZ,M0,M0,M1
 2125 FORMAT (R2,3I1,R1"_")
 2150 FORMAT (R2,3I1"_")
 2200 FORMAT (R2,3I1,R1,R2,3I1"_")
 2400 FORMAT (I4"_")
C
C--INCR STAGE PNTR WHEN NUMBER OF
C--PAGES IN CURRENT STAGE EXCEEDED
 1300 L=L+1
      IF (L.GE.PAGES(J)) L=0
      IF (L.EQ.0) J=J+1
      LOCM=LOC
 1500 CONTINUE
```

```
C
C--RETURN TO PRINT MODE
C—WHEN FINISHED PLOTTING
 1800 WRITE (6,2150) ESCA,MO,MO,MO
      WRITE (6,2100) ESCN
      WRITE (6,2000)
      WRITE (6,2500) MINS
 2500 FORMAT (////30X"STOP TIME: "I4)
      STOP 7777
      END
      END$
```

IS ON CR00011 USING 00017 BLKS R=0157

```
FTN4,L
      PROGRAM STATS,3
C-----------------------------------------------------
C  3/19/80
C
C  "STATS" COMPUTES SUMMARY STATISTICS FROM SLEEP
C  RECORDS.  RECORDS MUST HAVE BEEN ENTERED ON DISC
C  USING "INPUT" PROGRAM.                     JBW
C
C  CALL IS: (*)ON,STATS,TR,SEC, WHERE 'TR' & 'SEC'
C  ARE TRACK & SECTOR REFERENCES OF DISC FILE
C-----------------------------------------------------
      DIMENSION IBUF(64),IPRM(5),NX(7),NY(7)
      INTEGER PAGES(7,150)
      CALL RMPAR(IPRM)
      ITR=IPRM
      ISEC=IPRM(2)
C----------
C  INITIALIZATIONS
C----------
      DO 10 I=1,7
      NX(I)=0
      NY(I)=0
      DO 10 J=1,150
      PAGES(I,J)=0.
   10 CONTINUE
      NNY=0
      WASA=0.
      WASO=0.
      TOT=0.
      TOTS=0.
C----------
C  CHECK FOR CORRECT DISC
C----------
      CALL EXEC(1,107B,IBUF,64,0,0)
      IF (IBUF(1).EQ.3881) GO TO 50
      WRITE (4,40)
   40 FORMAT (" WRONG DISC")
      STOP 1111
C----------
C  CHECK FOR VALID SECTOR
C----------
   50 IF (MOD(ISEC,24).EQ.0) GO TO 70
      WRITE (4,60)
   60 FORMAT (" WRONG SECTOR")
      STOP 2222
C----------
C  MAKE SURE THERE IS DATA
C----------
   70 CALL EXEC (1,107B,IBUF,64,ITR,ISEC)
```

```
      IF (IBUF(35).EQ.3465) GO TO 100
      WRITE (4,90)
   90 FORMAT (" NO DATA")
      STOP 3333
C----------
C  WRITE ID INFO
C----------
  100 WRITE (6,110) (IBUF(I),I=1,30)
  110 FORMAT (/" SUBJECT: "30R1)
      WRITE (6,120) (IBUF(I),I=31,33)
  120 FORMAT (" DATE: "I2"/"I2"/"I2)
      IPM=IBUF(34)
      WRITE (6,130) IPM
  130 FORMAT (" PAPER SPEED: "I1" PAGES/MIN")
      WRITE (6,140) ITR,ISEC
  140 FORMAT (" DISC FILE: TRACK "I3" SECTOR "I2)
      PM=FLOAT(IPM)
C----------
C  READ PAGE & STAGE DATA
C----------
  150 ISEC=ISEC+1
      CALL EXEC (1,107B,IBUF,64,ITR,ISEC)
      DO 200 I=1,64,4
      IF (IBUF(I).EQ.7) GO TO 201
      ISTG=IBUF(I)+1
      IF (IBUF(I+2).NE.0) ISTRT=IBUF(I+2)
      IX=IBUF(I+1)-ISTRT
      NY(ISTG)=NY(ISTG)+1
      NNY=NNY+1
      NX(ISTG)=NX(ISTG)+IX
      PAGES(ISTG,NY(ISTG))=IX
      TOT=TOT+IX/PM
      WASO=WASO+WASA
      IF (ISTG.GT.1) TOTS=TOTS+IX/PM
      IF (NNY.GT.1.AND.ISTG.EQ.1) WASA=IX/PM
      IF (ISTG.NE.1) WASA=0.
      ISTRT=IBUF(I+1)
  200 CONTINUE
      GO TO 150
  201 WRITE (6,202)
  202 FORMAT (/" STAGE    N     DUR  MN DUR    % TOT   % SLP"
     -"  25%ILE  MEDIAN  75%ILE  I.Q.R."/)
C----------
C  RANK DURATIONS IN EACH STAGE
C----------
      I=1
  205 N1=NY(I)-1
  207 DO 210 J=1,N1
      J1=J+1
      IF (PAGES(I,J).LT.PAGES(I,J1)) GO TO 210
      ITEMP=PAGES(I,J)
      PAGES(I,J)=PAGES(I,J1)
      PAGES(I,J1)=ITEMP
  210 CONTINUE
```

```
      N1=N1-1
      IF (N1.GE.1) GO TO 207
      I=I+1
      IF (I.LT.8) GO TO 205
C----------
C  COMPUTE ORDER STATS
C----------
      DO 300 I=1,7
      IF (NY(I).EQ.0) GO TO 265
      IM=NY(I)/2+1
      IP=NY(I)/2
      IF (MOD(NY(I),2).EQ.0) GO TO 220
      QMED=PAGES(I,IM)/PM
      GO TO 225
  220 QMED=((PAGES(I,IP)+PAGES(I,IM))/2.)/PM
  225 IF (NY(I).LT.4) GO TO 255
      IQ1=IP/2+1
      IQ3=NY(I)-IQ1+1
      IF (MOD(IP,2).EQ.0) GO TO 230
      Q1=PAGES(I,IQ1)/PM
      Q3=PAGES(I,IQ3)/PM
      GO TO 250
  230 IP1=IP/2
      Q1=((PAGES(I,IP1)+PAGES(I,IQ1))/2.)/PM
      IQ3=NY(I)-IQ1+1
      IP3=NY(I)-IP1+1
      Q3=((PAGES(I,IP3)+PAGES(I,IQ3))/2.)/PM
  250 RI=(Q3-Q1)/2
      GO TO 260
  255 Q1=0.
      Q3=0.
      RI=0.
C----------
C  COMPUTE SUMMARY STATS
C----------
  260 DUR=NX(I)/PM
      TMEAN=DUR/TOT
      SMEAN=DUR/TOTS
      IF (I.EQ.1) SMEAN=0.
      DMEAN=DUR/NY(I)
      GO TO 270
C----------
C  ENTER ZEROS IF NO OCCURRENCES
C  OF THIS STAGE
C----------
  265 DUR=0.
      TMEAN=0.
      SMEAN=0.
      DMEAN=0.
      Q1=0.
      Q3=0.
      QMED=0.
      RI=0.
C----------
```

```
C  PRINT SUMMARY
C----------
  270 JSTG=I-1
      WRITE (6,295) JSTG,NY(I),DUR,DMEAN,TMEAN,SMEAN,Q1,QMED,Q3,RI
  295 FORMAT (I4,1X,I6,2F8.2,2F8.3,4F8.2)
  300 CONTINUE
      TSP=TOTS+WASO
      WRITE (6,350) NNY,TOT,TOTS,TSP,WASO
  350 FORMAT (/" TOTAL"I5,F8.2////12X"TST= "F8.2
     -"    TSP= "F8.2"    WASO= "F8.2)
      STOP
      END
      END$
```

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